Is the Phone Mightier than the Sword? Cell Phones and Insurgent Violence in Iraq [1]

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Abstract

Does improved communication as provided by modern cell phone technology affect the production of violence during insurgencies? A priori predictions are ambiguous, introducing cell phones can enhance insurgent communications but can also make it easier for the population to share information with counterinsurgents and creates passive signals intelligence collection opportunities. We provide the first systematic test of the effect of cell phone communication on conflict using data on Iraq's cell phone network and event data on violence. We show that increased mobile communications reduced insurgent violence in Iraq, both at the district level and for specific local coverage areas. The results provide support for models of insurgency that focus on the provision of information by non-combatants as the key constraint on violent groups and highlight the fact that small changes in the transaction costs of cooperating with the government can have large macro effects on conflict.

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Introduction

In 2007, cell phone subscriptions reached 3.3 billion worldwide, which corresponds to half the world's population (Virki 2007). The increase in wireless communication has been one of the most important technological advances of the last two decades. There are plenty of reasons to be enthusiastic about this progress. For example, economists have shown that improved mobile communications can enhance market performance in Indian fishing communities (Jensen 2011) and reduce price dispersion in grain markets in Niger (Aker 2008). At the same time, however, there are circumstances under which cell phone communication can have more pernicious effects. Governments are increasingly afraid of the potential for collective mobilization that is introduced by modern communication technology. During the early-2011 protests in Egypt, for example, the Mubarak government shut down all cell phone communications in an attempt to stop the large crowd of protesters from growing further (Richtel 2011). Analysts of organized crime, terrorism, and insurgency have long argued that the spread of cheap and reliable mobile communications will open up new organizational models for terrorists and rebels (see e.g. Arquilla, Ronfeldt, and Zanini 1999; Andreas 2002).

If cell phone communication is conducive to subversive action, insurgents should be among the keenest adopters of this technology. Anecdotal evidence from Iraq suggests this, with press reports labeling cell phones an "explosive tool for insurgents" (Washington Times 2005) and some arguing that mobile communications enabled a "networked insurgency" in Iraq (Muckian 2006). That cell phones can be key infrastructure for insurgent communication is corroborated by the observation that while insurgents in Iraq frequently attacked water and electricity networks, they carefully spared the cell phone network (Brand 2007), and even threatened telecommunication companies for not doing enough to maintain their network (Blakely 2005). This pattern from Iraq contrasts with anecdotes from Afghanistan, where the Taliban insurgents seem afraid of cell phone technology. They have issued decrees ordering all cell phone towers to be turned off during nightly hours, in an attempt to prevent villagers from calling in tips to the military forces (Trofimov 2010) and have attacked and destroyed cell phone towers for the same purpose (Shachtman 2008).

Theoretically it is not obvious whether or how the availability of cellular communications influences political violence. Cell phones make collective action easier; equipped with light, mobile communication devices, insurgents can easily coordinate actions, execute attacks and quickly react to counterinsurgency operations (see e.g. Cordesman 2005, Leahy 2005, Strother 2007). Following this line of reasoning, increased cell phone availability should lead to higher levels of violence. At the same time, however, cell phone availability could benefit counterinsurgents. In general, cell phones make it easier for the population to share information about insurgent activity, and to safely and anonymously call in tips. If this were true, and if the provision of information to counterinsurgents by the population were generally the binding constraint on the production of violence (Berman, Shapiro, and Felter 2011), then greater cell phone availability would lead to less violence. Insurgent use of cell phones, moreover, may create operational vulnerabilities given many governments' abilities to monitor them.

We make the first systematic attempt to examine whether cellular communications networks are security enhancing or not. Using detailed data on cell phone networks and violence in Iraq, we estimate the effect of cell phone network expansion on insurgent violence at two levels. First, because the insurgency was organized regionally, we conduct a district-level analysis, assessing whether increased coverage at the district level is associated with changes in violence. We find that better coverage at the district level leads to a clear and robust decrease in insurgent attacks for most of the war. Second, in order to provide evidence on the mechanisms behind the main district-level effects, we study the local effect of cell phone towers within specific coverage areas. Using a novel spatial-temporal difference-in-difference design, we show that after a tower is turned on, there is a large drop in the number of improvised explosive device (IED) attacks in the area around towers that introduce substantial new coverage, but not around towers that merely increase existing capacity. This finding is especially striking as cellular coverage opens up a broad range of technologies for fusing IEDs.

These results should inform the theoretical literature on non-state conflict in two ways. First, they highlight the centrality of civilian decision making over information provision in determining equilibrium levels of violence in civil conflicts. Specifically, our results show that in a conflict where rebels faced a militarily-competent government (i.e. Iraq and it's U.S. allies), exogenous reductions in the costs of communication (costs that should have increased the productivity of labor for rebels) led to reduced violence. This is powerful evidence for the theoretical approach laid out in Berman, Shapiro, and Felter (2011) and further evidence for the criticality of local information highlighted in Kalyvas (2006), Lyall

(2010), and Condra and Shapiro (2012). Second, and more broadly, they show that small changes in the transaction costs for communication can have dramatic effects on levels of violence. In our tower-level analysis the introduction of coverage decreases violence by about 40% from the mean level in areas that receive new coverage at some point. This is considerable effect, especially given that constructing a cellular tower in Iraq was quite cheap, $50-200k according to Zain. This result has implications for theoretical models of civil conflict, but also important consequences for policy. While it is typically assumed that violence reduction is costly, we show that it need not be; relatively simple and inexpensive measures can be very effective under the right circumstances.

Cell Phones and Insurgent Violence

Theories of insurgent violence and collective action provide conflicting predictions about the impact of introducing cellular communications into areas with ongoing violence. In particular in the context of the recent uprising in the Arab world, modern communication—and in particular cellphone technology—is frequently mentioned as a key catalyst of rebellion because it facilitates collective action. The argument is that by making it possible for people to coordinate mass protest, these technologies play a key role in toppling autocratic regimes and paving the way for democracy (Diamond 2010, Shirky 2011). This thinking is rooted in the social movements literature, which has shown that efficient communication critically affects a movement's capability for organizational mobilization (Garrett and Edwards 2007). In a different context, however, fast distribution of information between the members of a movement could also foster less favorable outcomes. During an insurgency, cellular communication technology could lead to increasing violence by making it easier for insurgents to coordinate attacks, mass forces, and by operating in a coordinated fashion without a defined chain of command.

There is ample evidence that some players in the Iraqi insurgency felt that cell phone networks were a boon to insurgents. In addition to facilitating improved coordination, cell phone service opened up a range of fusing options for improvised explosive devices (IEDs). With cellular coverage insurgents could call phones to detonate bombs, they could set up bombs that would detonate when Coalition jammers terminated a call, and they could communicate between spotters and those controlling an explosive, meaning that the controller no longer needed to be within line-of-sight of the IED (see Appendix Figure

A01). Given the manifest potential military advantages to insurgents of having cell phones, it is perhaps not to surprising that in 2005 the chairman of the Iraqi National Communications and Media Commission reported companies were being "threatened by terrorists for delays in setting up masts" because "Terrorists like mobile companies" (Blakely 2005).

Cell phone technology, however, can also improve information gathering by counterinsurgent forces, which would in turn lead to more effective counterinsurgency and a decrease in violence. The two key mechanisms that account for this are best understood in the context of the 'Hearts-and-Minds' (HAM) model presented in Berman, Shapiro, and Felter (2011), hereafter BSF. The model is formally introduced in BSF, so we focus on a non-technical discussion here. The HAM model is a 3-sided game between violent rebels seeking to impose costs on a government, a government seeking to minimize violence by a mix of militarized counterinsurgency efforts and service provision, and civilians deciding whether to share information about insurgents. Civilian decisions are based on their political preferences, the benefits of government service provision, the costs imposed on them by rebel violence, and the ability of rebels to retaliate against community members who share information. In equilibrium, rebels produce violence up to a 'non-cooperation constraint', the point at which the externalities of violence to the community are so high that the representative community member is indifferent between sharing information with the government or not, given their political preferences and exposure to rebel retaliation.[2] In extensions to the core model, BSF show that the non-cooperation constraint occurs at lower levels of insurgent violence when: (1) the level of collateral damage caused by government forces at a given level of military activity is lower; and (2) the ability of rebels to retaliate against those who share information is reduced.

Both of these parameters are directly affected by the introduction of cell phone technology. First, by using cell phone tracking, counterinsurgent forces can target the most influential insurgents while avoiding killing innocent civilians. This "signals intelligence" mechanism corresponds to (1). Second, cell phones make it easier for the civilian population to share information with counterinsurgents because they make it possible to place calls from more private places than with fixed land-line phones (of which there was not great market penetration in Iraq in any case), allow for SMS text messaging which cannot be

[2] Biddle, Friedman, and Shapiro (2012) provide evidence that in many places in Anbar governorate anger at the externalities created by al-Qa'ida in Iraq violence led locals to turn against that insurgent group.

overheard, and reduce the need for in-person meetings between government sources and their handlers. Cell phones thus reduce the insurgents' ability to identify and retaliate against people providing information. This "human intelligence" mechanism corresponds to (2).[3]

There is anecdotal evidence that both mechanisms were at work in Iraq. It was cell phone monitoring, in part, that helped U.S. forces kill several senior al-Qa'ida in Iraq leaders including Abu Musab al-Zarqawi (Perry et al. 2006) and many other AQI leaders (as well as Osama Bin Laden in Pakistan). At the same time, coalition forces considered human intelligence to be key and worked throughout the war to make it safer for people to provide it. Shortly after the invasion in 2003, the National Tips Hot Line was rolled out by the Coalition Provisional Authority with nearly $10 million budgeted for billboard, print, radio, and television advertising (Semple 2006).[4] Throughout Baghdad in 2004, the tip line was advertised as a way to "fight the war in secret" (Miles 2004). Soldiers in many areas carried cards advertising tip lines, such as the one shown in Appendix Figure A02 that was distributed by soldiers of the U.S. Army 3rd Infantry Division operating in al-Zubayr, near Basrah, in 2010. The idea behind these efforts was that many civilians opposed the insurgency enough to share useful information if they could do so safely, but not enough to take up arms on their own or join the police.

If cell phone technology affects insurgency in the way the HAM model predicts, there should be a general decline in violence associated with the introduction of this technology in conflict regions. This constitutes our first hypothesis, and establishing the causal direction of this effect is our main goal in this paper. However, our analysis does not stop here. Even if we can establish a general effect, we still do not know which mechanism is responsible for it. Direct tests of the signals and human intelligence mechanisms, however, are difficult, if not impossible. There exists no unclassified data on such information transfers; in fact, intelligence from human sources (HUMINT) is among the most highly-classified types of information held by the U.S. military. Concrete data on cell phone tracking is impossible to get due to similar sensitivities around signals intelligence (SIGINT).

[3] In the HAM model as presented in BSF the impact of cellular communications through these mechanisms would not depend on community norms (*n* in that model) because the authors assume an additive sub-utility function. Under other assumptions one could get different results.
[4] This form of local intelligence is of course not unique to insurgencies; police forces consider local communities to be key sources of information for preventing crime and terrorism, and ongoing policing efforts focus on forging trust and confidence between citizens and security forces (Innes 2006).

Instead, by examining effects across different kinds of attacks and at different levels of geographic aggregation, we can make the cautious case about how our results are consistent (or not) with different mechanisms. In particular, we distinguish between the effects of cell phone coverage in larger geographic units, and those in the direct vicinity of new cell phone towers. The former is relevant because insurgent violence need not be carried out where it is planned; rather, insurgents operate in a larger geographic radius. If we assume that cell phone coverage affects the planning stage of insurgent attacks or allows counterinsurgents to better target senior insurgents, we should study this effect in that area. Our first test thus focuses on administrative *districts* as unit of analysis.[5] We conduct a second analysis at a finer resolution, the coverage area around cell phone *towers*. These coverage areas typically have a radius of a few kilometers, and mostly correspond to small villages or settlements. This analysis intends to identify towers' influence on local tactical dynamics, either by making it safer for people to share information or by enhancing the viability of remotely fusing IEDs and helping to coordinating ambushes.

The two levels of analysis give us some leverage in distinguishing between the human- and signals intelligence mechanisms we describe above. We argue that the signals-intelligence channel predicts that increased coverage will be violence reducing at the district level, but not at the coverage-area level. This is because the benefits of signals intercepts accrue in large part from understanding key individuals who operate widely and so can be attacked far from the location of the initial information acquisition. The information-sharing channel, in contrast, predicts that increased coverage should be violence reducing at both levels because people living within a neighborhood are suddenly able to more safely share information about what is going on in their specific geographic space.

In sum, if cell phone communication affects insurgency according to the HAM model, we expect a general decrease in violence following the expansion of the network. If we see these effects both at the district- and the tower-level, this should support the human intelligence mechanism of information sharing. In contrast, identifying the effect at the district-level—but failure to do so at the tower level—constitutes evidence in favor of the signal intelligence mechanism as the main one. In following, we explain how we go about testing these expectations.

[5] There is some evidence that insurgents in Iraq organized along district lines, see Bahney et. al. (2011) on Al-Qa'ida in Iraq.

Data and Identification Strategy

Our analysis exploits variation in cell phone coverage introduced by the buildup of Iraq's network. In the following, we briefly describe the history of this network, our identification strategy, as well as our measure of violence and other control variables in our analysis.

Iraq's Cell Phone Network

Whereas under the regime of Saddam Hussein mobile communication was only accessible to a small minority of Iraqis, the network has seen a rapid expansion in the recent years. Less than 10% of Iraq's population of approximately 25 million people lived in areas with cell phone coverage at the beginning of 2004.[6] By February 2009, when our study period ends, Zain—Iraq's largest cell phone provider—alone reported over 10 million subscribers.[7] After coalition forces had invaded Iraq and toppled Saddam in 2003, the establishment of modern communication networks was a priority during the reconstruction efforts. In late 2003, the Iraqi government sold contracts to establish cell phone networks to three companies, one for each of three regions (northern, southern and central Iraq). In order to improve existing coverage and enable nation-wide competition, the government auctioned three licenses for national coverage in fall 2007, which also led to the creation of a nation-wide carrier, Zain.

The build-up of the cellphone network occurred in a phased approach, where providers first selected larger areas for expansion, and then chose specific sites for cell phone towers. We give a detailed account of this procedure and its practical details in the online appendix (A03) based on information from MEC Gulf, a consulting firm that advises cell phone companies (including Zain) on network expansion, as well as conversations with the Chief Technology Officers of the major Iraqi cellular firms. According to what we were told, network expansion was only marginally affected by the ongoing insurgency, both because larger expansion areas were selected at the beginning of each year based on marketing considerations, and because local placement of towers was affected by a variety of administrative procedures orthogonal to the ongoing conflict.

We use data on the coverage of the cell phone network that was made available to us by Zain Iraq and covers the period 2004-2009. Since Zain purchased other providers

[6] Authors' calculations based on coverage areas and Landscan population data.

[7] Zain Iraq website, http://www.iq.zain.com/iq/af/home.do?lang=en

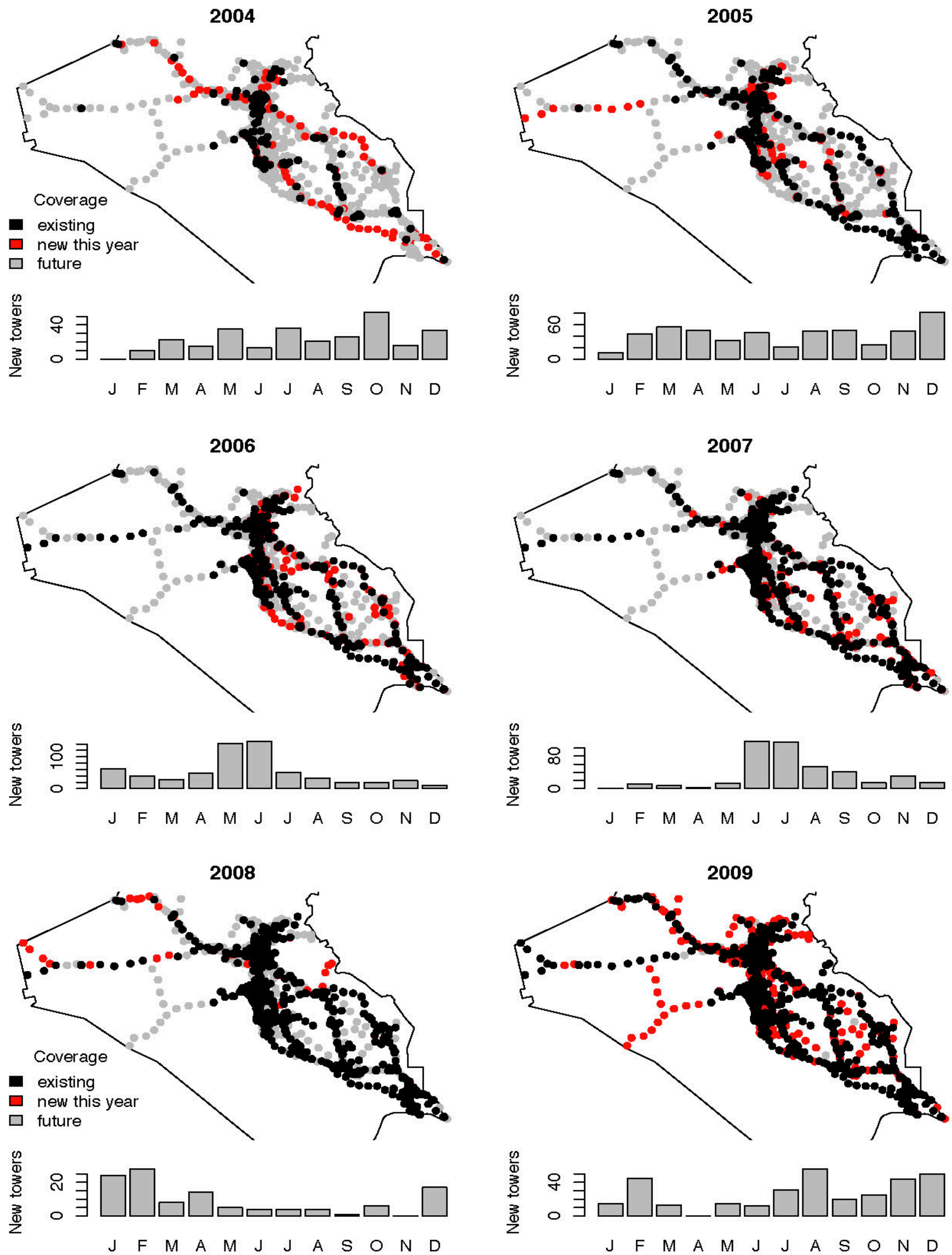
operating in central and southern Iraq in 2007 and 2008, our data include the vast majority of towers operating in areas of Iraq experiencing violence between 2004 and 2008. The original dataset records information on 7,687 cell phone antennas with their precise on-air date and geographic location. Antennas were installed in groups of two or three per cell phone tower, so that together they provided a roughly 360° coverage around the tower. From the original dataset we derived a tower dataset of 2,489 unique locations. Due to missing on-air dates, 73 of these towers were dropped, which leaves us with 2,416 towers included in the analysis. Figure 1 shows the expansion of the Iraqi cellular network.

Dependent Variable and Controls

Our measure of insurgent violence includes attacks against Coalition and Iraqi government forces, and is based on 193,264 'significant activity' (SIGACT) reports by Coalition forces. These reports capture a wide variety of information about "…executed enemy attacks targeted against coalition, Iraqi Security Forces (ISF), civilians, Iraqi infrastructure and government organizations" occurring between 4 February 2004 and 24 February 2009 (GAO 2007, DOD 2008). Unclassified data drawn from the MNF-I SIGACTS III Database were provided to the Empirical Studies of Conflict (ESOC) project in 2008 and 2009. These data provide the location, date, time, and type of attack incidents but do not include any information pertaining to the Coalition Force units involved, Coalition Force casualties or battle damage incurred. We filter the data to remove attacks we can identify as being directed at civilians or other insurgent groups, leaving us with a sample of 168,730 attack incidents.[8] Depending on level of analysis (see below), we aggregate these events either at the level of districts or tower coverage areas.

[8] We thank Lee Ewing for suggesting the filters we applied.

Figure 1: Expansion of the Zain Iraq Network, 2004-2009



To estimate the population we employ the fine-grained population data from LandScan (Oak Ridge National Laboratory 2008) aggregated to the district level. Estimates of a district's ethnic composition were obtained by combining these data with precise ethnic maps of Iraq. After collecting every map we could find of Iraq's ethnic mix, we geo-referenced them and combined them with the population data to generate estimates of the proportion of each district's population that fell into each of the three main groups (Sunni, Shia, Kurd). We coded districts as mixed if no ethnic group had more than 66% of the population, otherwise the district was coded as belonging to its dominant ethnic group. There were large population movements during the war, but the sectarian changes were concentrated in Baghdad and there they occurred mostly neighborhood-to-neighborhood, at smaller geographic units than we are using.

Identification Strategy

As we have motivated above, examining the impacts of coverage at both levels of geographic aggregation is important for two reasons. First, since we cannot test the hypothesized mechanisms of information sharing directly, we can use results at multiple levels of geographic aggregation in order to narrow down the mechanisms at work. Second, this approach is critical for assessing the policy relevance of the results. Results for smaller geographic units have ambiguous implications as coverage could reduce violence in small areas by reducing overall insurgent capacity, or by pushing insurgents to conduct attacks elsewhere (spatial displacement). We therefore conduct our analysis at two levels of analysis, the district- and the tower-level.

District-Level Empirical Approach.

At the district level we employ a standard panel data approach which is justified to the extent that we believe that controlling for factors such as the number of pre-existing towers in a district, or time and space fixed effects, will account for core drivers of network expansion that are also correlated with violence.[9] We might, for example, be concerned that expansion of the network is influenced by economic activity, which appears to be positively correlated with insurgent violence in Iraq (Berman, Callen, Felter, and Shapiro 2011), and so want to

[9] Appendix Table A04 shows descriptive statistics for the district-level data, which includes only the 63 districts in which Zain operated during the period of analysis.

estimate the impact of coverage on violence in first-differences to account for unit-specific trends.[10] So how viable is this approach?

Given what we know about how the network was built (as described in Appendix A03), it is extremely unlikely that month-to-month variation in violence impacted the network's construction. In numerous conversations with those who built the network nobody reported major design changes being made in response to existing or anticipated insurgent violence. Site acquisition teams were reportedly able to build towers even in the context of difficult security situations such as Fallujah in 2004 and Ramadi in 2006. The teams would typically enter into long-term contracts with community members to pay for site rental, generator fueling, and site security, as well as training local engineers to provide these services. Where possible, they worked through local elites to identify the personnel who could be entrusted with these jobs. This strategy meant that once marketing had identified an area for network expansion, teams were able to move in effectively even in areas with high violence.

Many factors orthogonal to violence, however, clearly did influence tower construction, often in ways that lead us to believe the month-to-month timing had a large random component. Towers were delayed due to unpredictable decisions by government officials, difficulties in identifying whether a potential lessor actually held title to the desired site, and disputes that arose once a site had been selected as the value of the lease and servicing contracts drew interested parties to make claims to land. Given these risks, the major firms employed what they described as a "scatter-shot" approach in which they would try to secure title to all of the sites in their expansion plan as soon as site-selection was complete. As a practical matter, this meant they often built out in a different order than the marketing or service provision priorities alone would have dictated.

The variability in the rate of new tower construction is shown in Appendix Figures A05 and A06, which together highlight two patterns. First, there is tremendous month-to-month variation in the rate of new tower introduction, both within periods of high violence and during periods of peace. Second, there appears to be some correlation between extremely high violence and low tower introduction in a few places (Al-Muqdadiyah in Baghdad in 2007 for example), and nationally from August 2006 to July 2007. Adequately

[10] Formally, we can correctly identify the causal effect of network expansion if the treatment (month-to-month changes in the network) is independent of the outcome (insurgent violence) conditional on controls.

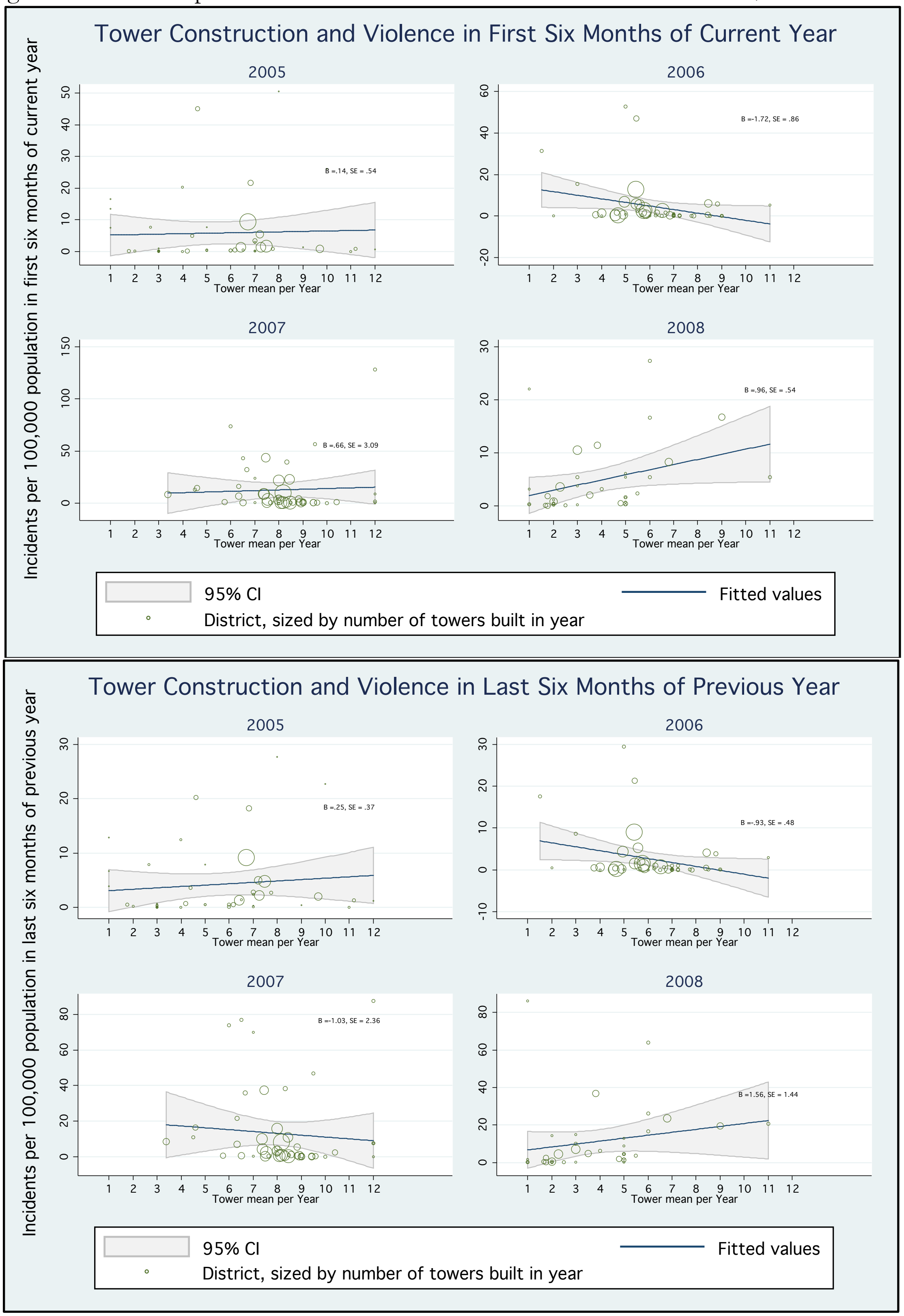
controlling for broad secular trends is therefore key to estimating the effect of towers on violence.

To conduct a more direct test of whether tower construction at the district level was consistently influenced by violence trends, we plot the average date of tower introduction within a district in a given year on the levels of violence in: (a) the last six months of violence in the previous year and (b) the first six months of violence in a given year. If tower construction is delayed by levels of violence at the end of the previous year, which would have made it harder to adjudicate titles, that would lead to a positive slope as the average date of introduction was pushed back. If towers were being introduced in ways that avoided violent districts, we should see a positive slope for the second plot as tower construction teams avoid highly violent places and so delay construction.

Neither was the case. Figure 2 shows that there is no consistent pattern across years at the district level. The top panel shows the relationship between levels of violence in the last six months of a year (plotted on the y-axis) and the average date of tower introduction in the next year (plotted on the x-axis). The bottom panel shows the relationship across years between levels of violence in the first six months of a year (plotted on the y-axis) and the mean date of tower introduction (plotted on the bottom panel). Only one of the bivariate correlations shown in the figure is statistically significant at the 95% level (the relationship between average date of tower introduction and violence in the direst six months of the current year), and that one is in the opposite of the expected direction. All these correlations become substantively small and statistically insignificant when the years are pooled or when sect fixed-effects are added to account for the average differences between purely Sunni regions where the nationalist insurgency dominated, and mixed regions which faced both a nationalist insurgency and a sectarian civil war.[11]

[11] A similar plot for the violence in the last 6 months of the current year is in Appendix Figure A07. Results of regressions pooling across years and adding controls to account for differences between them are in Appendix Table A08.

Figure 2: Relationship between Violence and Tower Construction at District/Month



Our core specification at the district level is therefore a first-differences approach,

$$\nu_{i,t+1} - \nu_{i,t} = \alpha + \beta_1(\text{towers}_{i,t} - \text{towers}_{i,t-1}) + f_i + \delta_t + \epsilon_{i,t}, \quad (3)$$

where f_i is a district fixed-effect and δ_t is a time-fixed effect. We lag the difference in tower construction by one month to prevent simultaneity bias.

Importantly, the requirement for this approach to provide an unbiased estimate of the impact of cell-phone coverage on violence is not that we control for all other factors which could affect violence, rather, it is that the fixed effects control for those factors which are also correlated with changes in the number of towers. Based on what we know about the process of expanding the network, none of the factors affecting the month-to-month timing of the introduction of towers (e.g. the availability of clean titles to desired locations) are likely to vary in ways not accounted for by time and space fixed-effects.[12] Figure 2 provides strong evidence that they did not and we will show that our results are robust to the inclusion of a broad range of time and space fixed-effects. More importantly, the core results pass both geographic and temporal placebo tests, providing confidence that the results are not driven by district-specific trends or by region-specific omitted variables.

Tower-Level Empirical Approach. For our tower-level analysis, we require approximations of the towers' coverage areas. We approximate the coverage of individual towers by a circular area. Depending on whether a tower is located in an urban or rural area, we assign a short radius or a long radius. In conversations with electrical engineers we determined radii of 4 km and 12 km to be good first-order approximations of the coverage areas given the equipment used on the towers and their spacing, but we also conduct robustness checks with alternative ones. [13] Estimating more precise coverage areas entails substantial complications and so for purposes of this paper we restrict ourselves to approximating coverage.

[12] As we discuss below, Appendix A12 checks for the possibility that past sectarian violence is an omitted variable impacting both the difficulty of obtaining title and trends in violence, finding no evidence that it is.
[13] Precise coverage estimates do not exist for Iraq and all major modeling software requires substantial input we have not been able to get from Zain. The 12km and 4km figures are based on an extensive effort to precisely model Zain's coverage with colleagues in Electrical Engineering, Professor Mung Chiang and Dr. Haris Kremo. Details available upon request.

The key to our tower level approach is that some towers simply enhance service that was already available, while other towers extend service into new areas. If violence declines because towers are introduced, and not because of some omitted variable driving introduction and violence, we should see violence goes down around towers that provide new coverage, but not around those that simply enhance existing service. If, however, violence declines because of some omitted variable, say because the providers are good at anticipating where violence will drop, we should see post-introduction declines in both areas.

An effective way to implement this approach is to use a standard difference-in-differences design where our estimate of the treatment effect is just E[($\mathbf{a}_{\mathbf{post}}$ - $\mathbf{a}_{\mathbf{pre}}$) - ($\mathbf{b}_{\mathbf{post}}$ - $\mathbf{b}_{\mathbf{pre}}$)] where **a** is a vector of violence in towers that provide new coverage and **b** is the analogous vector for towers that simply deepen existing coverage. This logic gives us the following core estimating equation:

$$v_{i,t} = \beta_1 post_t + \beta_2 (post_t * new_i) + f_i + q_t + \varepsilon_{i,t} \quad , \tag{4}$$

where f_i is a slice fixed-effect, q_t is a quarter fixed effect to control for secular trends in the conflict, the $post_t$ variable is a dummy variable that takes a value of 1 after tower introduction, and $pos_t * new_i$ is a dummy variable which takes a value of 1 in new coverage areas after towers are turned on. Since the threshold for what should constitute a new coverage area is not obvious, Zain always sought some overlap so there are almost no entirely new areas, our core analysis shows what happens as we vary the threshold for being a 'new' tower from 10% new coverage to 90%. The key coefficient to focus on is β_2 , which tells us how much the trend around towers that provide substantial new coverage differs from the trend around similar towers that extend existing coverage.

Appendix Table A09 provides descriptive statistics for the 1,859 coverage areas created by towers established between 14 June 2004 and 26 October 2008, of which 1,787 experienced at least one violence incident in our data. These are the slices for which we have eight full 15-day periods of violence data (120 days) before and after the towers were established. Panels (A) and (B) provide key characteristics for the full sample, panels (C) and (D) do the same for the towers that are have at least a 50% overlap with existing towers, and panels (E) and (F) provide information for towers that cover more than 50% new territory. As we can see, towers reinforcing existing coverage typically serve larger populations and experience more total violence, though substantially less per capita. This is, of course, because few new towers are needed in sparsely populated rural areas, while increasing adoption of cell phones created demand for greater capacity in urban areas, requiring Zain to introduce more towers and 'split cells' to maintain service and maximize its profits. Under the identifying assumption for the difference-in-differences estimate, that differencing accounts for unit-specific characteristics, these time invariant differences in slices should not bias the estimation, though we will discuss how it might and why we think it unlikely.

Results

This section analyzes the impact of expanding the cell phone network on violence at the district- and the tower level. First, we analyze district-level effects using standard panel data techniques, and provide a series of robustness checks. Second, we briefly describe additional results by attack type and sectarian area, the details for which can be found in the online appendix. Third, we analyze the effect of introducing coverage over towers' coverage areas.

District-level

At the district level, we find that adding additional cell phone coverage decreases violence. Table 1 present the core specification in first differences t0 nets out district-specific factors such as the anticipated long-term economic value of the district, which might impact trends in both insurgent violence and the introduction of cell phones. The results in differences are smaller but remain statistically significant once we control for national changes using time fixed-effects for the quarter-year (column 2) or month (column 3). Adding a district fixed-effect in addition to differencing (column 4) shows the results are robust to controlling for time-invariant district effects in addition to district-specific trends. Allowing the fixed effects to vary across the intersections of time and ethnic regions in columns (5 and 6) accounts for the fact that trends in the war were quite heterogeneous across different regions. The peak violence in Anbar province where Sunni tribes were fighting a nationalist insurgency, for example, came six months before violence peaked in Baghdad where Sunni and Shia militias were engaged in a sectarian conflict. The result remain substantively similar and statistically strong even when we include a district fixed effect and net out the average violence in the each of the 13 provinces each quarter (column 7), an extremely robust way to control for the geographically-specific trends in the conflict and in incentives to build towers. Appendix Tables A10 shows the results of the most stringent specifications (columns 4 and 7) are robust to the inclusion of the spatial lag of violence as an additional control.

Table 1. Impact of Increased Cell Phone Coverage on Total Attacks – District/Month

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable:	FD of SIGACTS /100,000						
Lagged First Difference of Tower Count	-0.0780 (0.047)	-0.0882* (0.049)	-0.115** (0.056)	-0.149** (0.070)	-0.0887* (0.054)	-0.0952* (0.055)	-0.188* (0.11)
Observations	3654	3654	3654	3654	3654	3654	3654
R-squared	0.01	0.01	0.07	0.07	0.03	0.06	0.07
Time FE	Half	Quarter	Month	Month	Sect X Half	Sect X Quarter	Province X Quarter
Space FE	No	No	No	District	No	No	No

Notes: Robust standard errors, clustered at the district level in parentheses. Estimates which are significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***).

Overall, the introduction of new towers correlates with less violence no matter how we handle secular trends in violence. In the most stringent model, column (7), a one standard deviation increase in the number of towers in a district (1.8) predicts 1.1 less attacks (-.188 * 3.27 * 1.8) in the following month, a 10% decrease from the mean level of violence. In appendix sections A11-A13 we provide tests that suggest the results are not driven by: (1) omitted variables driving trends in both violence and tower construction; (2) the direct impact of violence on future tower construction; or (3) enhanced coverage making insurgents more effective, allowing them to conduct more lethal attacks (e.g. shifting from a large number of small ambushes to a small number of large complex attacks). Taken together, these checks provide additional confidence that the combination of differencing and fixed effects in Table 1 properly identify the causal impact of tower construction at the district-month level.

Variation in District-level Effects

The effect of expanded cell phone coverage on insurgent attacks varies in informative ways across different insurgent tactics and across sectarian areas. Different kinds of insurgent attacks have different sensitivities to the productivity of labor and to information sharing by the population. In particular, direct fire attacks (e.g. ambushes) typically involve multiple individuals coordinating their actions but are sensitive to information sharing by the population, which can observe insurgents setting up. Indirect fire attacks (e.g. mortars) require less coordination and are less sensitive to information sharing as insurgents have great flexibility in choosing their firing position. IED attacks, require much less coordination around the point of attack than direct fire attacks and reveal less information to non-combatants, but remain sensitive to tips relative to indirect fire attacks, especially as tips about weapons caches can remove a large number of IEDs from circulation.[14]

Table 2. Impact of Increased Cell Phone Coverage by Attack Type

Dependent Variable: FD of Attacks/100,000	(1) All Attacks	(2) Direct Fire	(3) Indirect Fire	(4) Total IED Attempts	(5) IEDs Cleared / Total Attempts
Panel A: Full Sample					
Lagged FD of Towers	-0.149**	-0.0449	0.00525	-0.065*	-0.003
	(0.070)	(0.033)	(0.0083)	(0.037)	(0.004)
Observations	3654	3654	3654	3654	1701
R-squared	0.07	0.03	0.09	0.05	0.02
Panel B: Full Sample with Spatial Lag					
Lagged FD of Towers	-0.140**	-0.0443	0.0049	-0.056*	-0.0027
	(0.069)	(0.033)	(0.008)	(0.032)	(0.004)
Spatial Lag of DV	0.0323***	0.0106**	0.0022	0.0433***	-0.0326
	(0.008)	(0.0042)	(0.004)	(0.013)	(0.030)
Observations	3654	3654	3654	3654	1701
R-squared	0.12	0.04	0.09	0.12	0.02
Panel C: Without 2008					
Lagged FD of Towers	-0.184**	-0.0631*	0.0045	-0.075**	0.0000
	(0.075)	(0.037)	(0.009)	(0.036)	(0.001)
Observations	2898	2898	2898	2898	2898
R-squared	0.07	0.03	0.09	0.06	0.05
Panel D: With Period-Specific District Fixed-Effects (Period Breaks at August 2006 and June 2007)					
Lagged FD of Towers	-0.149**	-0.050	0.007	-0.062*	-0.0007
	(0.068)	(0.034)	(0.008)	(0.034)	(0.001)

[14] Direct fire weapons such as AK-47s are ubiquitous throughout Iraq and so their supply is unlikely to be as sensitive to raids being conducted on the basis of tips.

Observations	3654	3654	3654	3654	3654
R-squared	0.11	0.05	0.12	0.08	0.04

Notes: Robust standard errors, clustered at the district level in parentheses. All results include district and month fixed effects. Estimates which are significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***). Column (5) calculated only for period when data distinguish between successful and failed IED attacks.

As Table 2 shows, emplacing more towers reduces all types of attacks, but has heterogeneous effects across the three main attack types. Panel (A) of Table 2 reports the core first differences model for each type of attack with district and month fixed effects, analogous to column (7) of Table 1. The effect is negative, but not statistically significant for direct fire attacks and positive but not statistically significant for indirect fire attacks. The effect is negative and statistically significant for total IED attacks attempted. The substantive effects are meaningful but not large. A one standard deviation increase in the number of towers introduced reduces the number of direct fire attacks in an average district-month by approximately 6.5%, and reduces the number of IEDs attempted by approximately 8.1%.

Table 3. Impact of Increased Cell Phone Coverage by Sectarian Area

Dependent Variable: Attacks/100,000	(1) All Areas	(2) Mixed	(3) Kurd/Shia	(4) Sunni	(5) Mixed/Sunni	(6) Ethnically Homogenous	(7) Non-Homogenous
Lagged FD of Towers	-0.149** (0.070)	-0.251 (0.19)	-0.00960 (0.058)	-2.259* (1.07)	-0.496* (0.29)	-0.195** (0.083)	-0.184 (0.15)
Observations	3654	580	2436	638	1218	2784	870
Number of Districts	63	10	42	11	21	48	15
R-squared	0.07	0.30	0.10	0.23	0.18	0.06	0.21

Notes: Robust standard errors, clustered at the district level in parentheses. All results include month and district fixed effects. Estimates which are significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***).

What about variation across different sectarian areas? As Table 3 shows, it turns out that the results are substantively strongest in Sunni areas where per capita violence was highest. Column (1) of the table reports our core first differences specification, and the remaining columns report the results for different sectarian subsets of the data. Column (5) combines Sunni and mixed areas, showing that the average effect across the parts of the country where the war was really fought is negative and substantively modest, so that a one standard deviation increase in towers in these areas led to 3.9 fewer attacks in the next month (1.9*-.496*4.176), a 12.3% reduction. Columns (6) report the results for ethnically homogenous districts, where 80% of the population or more is from one sect, and column (7) shows the results for non-homogenous districts. The effects are substantively similar across these areas, with the standard errors being much larger in the non-homogenous districts because of the smaller sample size. Appendix Table A14 breaks these results down by both attack type and sectarian region, showing that the effects are driven by Sunni and mixed areas, which makes sense as there were relatively few insurgent attacks in Shia and Kurdish districts, and that the reduction in direct fire attacks is strongest in Sunni areas is far and away the strongest effect.

These patterns imply first that the human intelligence mechanism is key. Expanding coverage creates new collection channels for signals intelligence in all regions, but we expect the impact of providing people a safer way to share tips to be larger in Sunni areas because (a) Coalition forces' ability to run human sources would be weakest and (b) in-group policing by insurgents would be most effective. If you agree with that expectation, then the fact that these areas see the largest proportional declines from introducing coverage should be suggestive. Second, the fact that the effects are of similar magnitude for direct fire and IED attacks (nearly identical if we drop 2008 from the analysis), makes it seem unlikely that expanding coverage substantially eased coordination. If it had, the effect on direct fire attacks, which require more coordination, should have been muted.

Tower-level Results

As described above, our tower-level analysis employs a before/after difference-in-differences design that compares tower introducing new coverage ("new towers") to those that mainly reinforce existing one ("reinforcing towers").

Table 4: Impact of Introducing Cellular Communications for Tower Areas.

Panel A: Standard Difference-in-Differences					
Coverage	(1)	(2)	(3)	(4)	(5)
Threshold for	10%	30%	50%	70%	90%

`New' Towers					
Post	1.093*** (0.21)	1.009*** (0.19)	0.967*** (0.19)	0.930*** (0.19)	0.911*** (0.18)
*Post*New*	-1.001*** (0.31)	-0.904** (0.37)	-0.737*** (0.27)	-0.520* (0.28)	-0.423 (0.32)
Observations	29,744	29,744	29,744	29,744	29,744
Number of Towers	1,859	1,859	1,859	1,859	1,859
R-squared	0.74	0.74	0.74	0.74	0.74
Panel B: Quarter Fixed-Effects to Control for Secular Trends					
Post	-0.0779 (0.20)	-0.169 (0.19)	-0.219 (0.18)	-0.243 (0.18)	-0.266 (0.18)
*Post*New*	-1.026*** (0.32)	-0.901** (0.40)	-0.677** (0.31)	-0.599* (0.34)	-0.487 (0.39)
Observations	29,744	29,744	29,744	29,744	29,744
Number of Towers	1,859	1,859	1,859	1,859	1,859
R-squared	0.75	0.75	0.75	0.75	0.75

Notes: Robust standard errors, clustered at the tower level in parentheses. All specifications include tower fixed effects. Estimates significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***).

Table 4 shows that mean levels of violence per 15-day period at the tower level are much lower in the 120 days after the on-air date for new towers, but not for reinforcing ones. Panel (A) shows the results of the standard difference-in-differences regression, which does not account for secular trends. Panel (B) shows the results controlling for broad secular trends with quarter fixed-effects. The difference is striking. The positive change in average per-period violence after introduction of a reinforcing tower that we see in panel (A) is an artifact of secular trends. Once quarter fixed-effects are added, the positive mean shift disappears but the negative mean shift in areas where towers add 10% or more new coverage remains substantively and statistically strong. Indeed, in panel (B) the reduction in violence from new towers is statistically robust and substantively consistent across coverage thresholds. At the 50% threshold, turning on a new tower predicts .896 fewer attacks per period, more than half the mean level of violence in tower areas that provide 50% new coverage.

Once we net out the broad secular trends, it appears that introducing coverage is violence reducing at the local level, but that building reinforcing towers is not. Table 5 shows that, just as with the district-level results, the effect is statistically strongest for IED attacks.

The impact of coverage is positive for indirect fire attacks but statistically insignificant for more lenient interpretations of what constitutes new coverage. This is consistent with an information mechanism in so far as it indicates tactical substitution wherein insurgents seeking to attack newly-covered areas do so with methods that do not require that they physically go there.

Table 5. Impact of Increased Cell Phone Coverage by Attack Type at Different Thresholds

Dependent Variable:	(1) All Attacks	(2) Direct Fire	(3) Indirect Fire	(4) Total IED Attempts
Panel A: Coverage Threshold for `New' Towers = 20%				
Post	-0.147	-0.168	-0.0213	-0.0725
	(0.19)	(0.11)	(0.042)	(0.088)
*Post*New*	-0.920**	-0.248	0.0629	-0.427***
	(0.37)	(0.19)	(0.050)	(0.13)
Observations	29744	29744	29744	29744
R-squared	0.75	0.64	0.31	0.80
Panel B: Coverage Threshold for `New' Towers = 50%				
Post	-0.219	-0.189*	-0.0253	-0.0898
	(0.18)	(0.10)	(0.041)	(0.085)
*Post*New*	-0.677**	-0.164	0.124**	-0.452***
	(0.31)	(0.16)	(0.056)	(0.13)
Observations	29744	29744	29744	29744
R-squared	0.75	0.64	0.31	0.80
Panel C: Coverage Threshold for `New' Towers = 80%				
Post	-0.252	-0.197**	-0.0248	-0.108
	(0.18)	(0.097)	(0.040)	(0.083)
*Post*New*	-0.547	-0.133	0.167***	-0.410***
	(0.35)	(0.17)	(0.058)	(0.15)
Observations	29744	29744	29744	29744
R-squared	0.75	0.64	0.31	0.80

Notes: Robust standard errors, clustered at the tower level in parentheses. All specifications include tower and quarter fixed effects. Estimates significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***).

The tower-level effects do vary a bit by period, though the introduction of new coverage always reduces violence relative to overall trends in tower catchment areas that do not expand coverage. Appendix Table A15 reports these results by attack type. Panel A excludes towers turned on during the period in 2006-7 when tower construction slowed. Panel B drops towers built after 2007. The results mirror those in the full sample as there is a clear negative impact of towers that provide at least 20% new coverage on IED attacks relative to the change in tower catchments that provide less than that. Our ability to control for broad secular trends in areas getting new towers is reduced when we exclude certain periods (the mean shift after reinforcing tower introduction is statistically significant in many of these models), however the core result that violence drops more in new tower catchments (the interaction term) remains robust.

For one to believe the tower-level results are driven by omitted variable bias, the correlation between future violence and the week-to-week timing of where towers are placed would have to be massively stronger for new towers than for reinforcing towers installed at the same time. That seems unlikely, particularly as the correlation between the proportion of new coverage a tower provides and total violence over the 120 days after construction is negligible once district-specific violence has been taken into account.[15]

Overall then, the tower level results provide additional evidence that the human intelligence mechanism is driving the panel data results. Introducing cell phone coverage has a clear localized impact in reducing the number of IEDs in new coverage areas but not in previously covered ones. This is particularly striking as putting coverage over an area increases the range of IED fusing options which should, if anything, decrease the proportion counterinsurgents can successfully neutralize.

Conclusion

This paper presents the first systematic examination of the effect of cellular communications on political violence using novel micro-level data from Iraq. We find that cell phone network expansion reduced insurgent violence at both the district-level and within specific tower coverage areas. Taken together, these findings suggest the mechanism driving the impact of cellular communications on violence is increased information flow to counterinsurgents. Our data are ambiguous about whether this is because coverage enhances voluntary information flow from non-combatants by reducing the risks of informing, or because insurgents using

[15] In other words, controlling for violence at a level of geographic aggregation that is much larger than the tower-specific fixed effects used in all the regressions in this section removes the correlation we would expect if there were a strong relationship between violence and the amount of new coverage towers provide. Results available on request.

cell phones present a good target for government intelligence gathering efforts, but the net effect is clear. We expect similar results to hold wherever government security services (and potentially their allies) have a robust ability to act on the increase in human and signals intelligence that expanded cellular coverage provides.

These results speak to a number of literatures. First, they contribute to a growing body of literature demonstrating the beneficial effects of expanding communications opportunities (Jensen 2011, Aker 2008). Our findings suggest cellular communications may confer a range of governance and stability advantages that have not previously been tested in this literature. Second, they highlight the importance of civilian decisions that fall far below the threshold of actually participating in the conflict and are not subject to collective action problems. That such decisions can be critical suggests political science theories may have greatly overestimated what it takes to dramatically change the dynamics of conflicts.

Third, the results also speak to debates about what kinds of ethnic concentrations increase the risk of civil war (Weidmann 2009) and to discussions of why insurgencies are more successful when operating from rural areas (Kocher 2004; Bates 2008; Staniland 2010). The question at issue in these debates is whether urban terrain makes it easier or harder for state security forces to control violent groups. The key argument on the 'easier' side is that in urban areas many people necessarily have information on the insurgents, by virtue of simple population density, which makes them acutely vulnerable to informants. By showing that exogenous environmental changes which reduce the cost of informing leads to a clear and unambiguous reduction in insurgent violence, we provide solid empirical grounding for a mechanism discussed, but never tested, in this literature.

Fourth, and perhaps most importantly, these results are highly relevant to ongoing policy in all countries facing active insurgencies and the need to grow their wireless infrastructure. For countries such as Colombia, India, Pakistan, and Thailand, the policy debates typically hinge on how tightly regulated access to phones and SIM cards should be. For the international community the debates are about the extent to which the expansion of cellular communications should be subsidized. In Afghanistan, for example, there has been an ongoing discussion about whether or not foreign governments and aid agencies should work with telecommunications firms that make compromises with local militants in order to protect their towers and staff. Much of the policy community currently argues there should be little engagement so long as towers are being turned off at night when the Taliban demands. Our analysis suggests this approach may be wrong-headed. If in addition to their economic impact towers that are on only part of the day confer counterinsurgency benefits, as we show towers which are on all day did in Iraq, then the international community may well want to subsidize the expansion of the Afghan cell phone network regardless of how the firms managing the network interact with the locals.

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Online Appendix for
"Is the Phone Mightier than the Sword? Cell Phones and Insurgent Violence in Iraq"

September 3, 2012

Contents (listed in the order in which they are referenced in the main article)

A01. Figure: Cell phone-triggered IED

A02. Figure: Card advertising the tip line in Iraq

A card handed out by soldiers from the U.S. Army 3rd Infantry Division providing contact information for a government-run tip line. The card reads as follows:

> "Have you seen, heard or become aware of criminal activities or those hostile to Iraq? Do you wish you could do something about it? You can!! Talk anonymously and help your country by giving news about crimes or actions hostile to Iraq. Fulfill your duty to take care of your children, your loved ones and society. You may phone or text to this number: 07712477623. Give any information you want, no names needed. The way YOU can fight is by calling this number: 07712477623."

A03. Description of the expansion of Iraq's cell phone network

Since our analysis exploits the expansion of the network in Iraq to assess cellular communications' effects on violence, a close look at the micro-dynamics of network expansion is necessary and provides crucial background for our identification strategy. The following description is based on extended conversations with MEC Gulf, a consulting firm that advises cell phone companies on network expansion, as well as the chief technology officers for *Zain Iraq* and *Asiacell*, two of the three major telecommunications providers in Iraq. It represents a consensus view, though details varied across firms, over time, and between projects.

Development of the cellular communications network in Iraq was based on a phased approach in which firms first selected larger areas for expansion, and then chose specific sites for cell phone towers within these areas based on the practicalities of providing coverage at minimum cost. For both Zain and Asiacell, areas for expansion were selected on an annual basis (towards the end of each company's fiscal year) based on three core criteria: requirements to meet service standards in existing areas as usage picked up; demand for cell phone service (large population without service); and contiguity with pre-existing coverage areas. An area chosen for expansion would typically be a large town, such as Fallujah, which first received coverage in 2004, or a semi-rural area with a large number of small communities.

Once these larger areas were selected, the radio-frequency (RF) design teams would map out a coverage plan that met a number of criteria including minimizing the number of towers while maximizing coverage and backhaul capacity. Two factors made their task more challenging in Iraq. First, the network backhaul in Iraq—the transmission of signals from the tower to a switch and then back out to the appropriate tower—occurred mostly via microwave as the country had no fiber optic network. Towers were therefore placed more closely together than in other settings to avoid interference from the microwave signals between towers.[1] Second, the pervasive use of jammers in Iraq by both Coalition forces and civilians meant that the providers needed to broadcast a stronger signal to guarantee coverage inside buildings than would be the case in normal urban settings.

Taking these constraints into account, the RF design teams would identify search rings of approximately one block radius in a number of locations within the targeted areas. Within these rings, a site selection team would then identify two or three potential sites that were suitable for tower installation. These would typically be buildings that had a relatively unobstructed view, but at the same time could support the weight of a cell phone antenna and the supporting equipment (generator). Once a list of candidate buildings had been put together, the respective proprietor of the

[1] The microwave signals between towers are highly directional. If towers were placed too far apart, there would be interference in those signals between towers, as the beam from one tower to the other would spread beyond the width of the receiving antenna.

building or the landowner would be contacted regarding a possible lease by the site acquisition team. If a search ring were deemed to be in an inaccessible area, then the RF design team would typically need to identify new search rings for multiple towers, not just the one initially sited in an inaccessible area. Typically, it would take two to three months for the market research process of identifying target expansion areas, about a month for the RF design, and then another two to three months from the establishment of the initial search rings to the completion of the final site list with sites secured, leased and ready to build. The setup of towers themselves would take anything from a couple of days (for rooftop sites) to a few weeks (for ground towers in more rural areas).

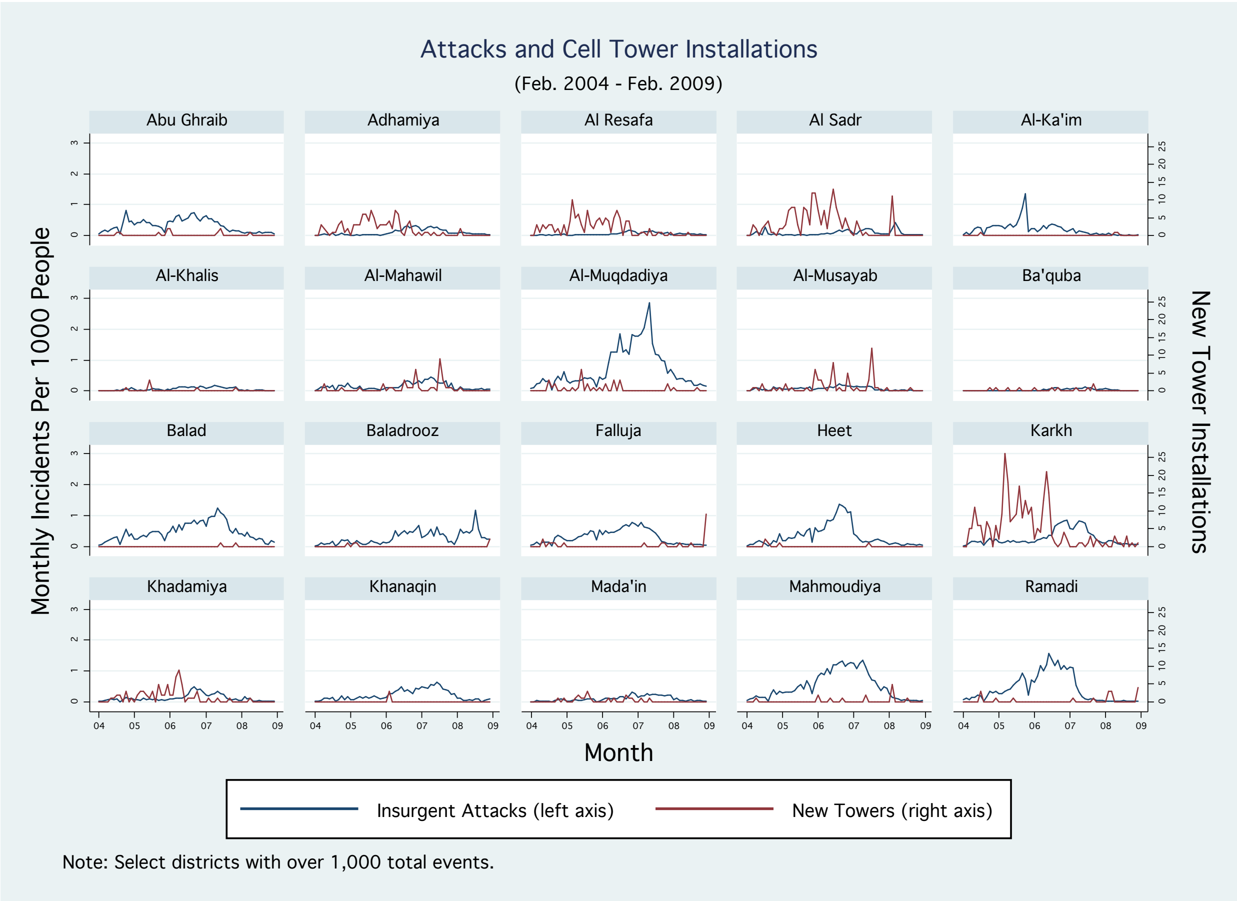
Figure 1 in the paper illustrates the expansion of the network graphically. Existing towers are shown in black, towers added in the respective year in red, and future towers in gray.

A04. Table: Descriptive statistics for the district-level data

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Panel A: Violence Variables					
SIGACTs / 100,000	3,780	13.21	34.92	0	481
Attacks / 100,000	3,780	12.04	32.82	0	453
Direct Fire / 100,000	3,780	3.25	10.26	0	156
IED Attempts /100,000	3,780	6.91	19.76	0	311
Sectarian Killings/100,000	3,780	1.79	6.63	0	170
Targeted Killings/100,000	3,780	0.648	4.74	0	170
Panel B: Control Variables					
New Towers	3,780	0.519	1.833	0	35
Total Towers Active	3,780	18.74	38.67	0	296
Population (1000)	3,780	327	320	11	1662
Proportion Sunni	3,780	0.243	0.355	0	1
Proportion Shia	3,780	0.742	0.371	0	1

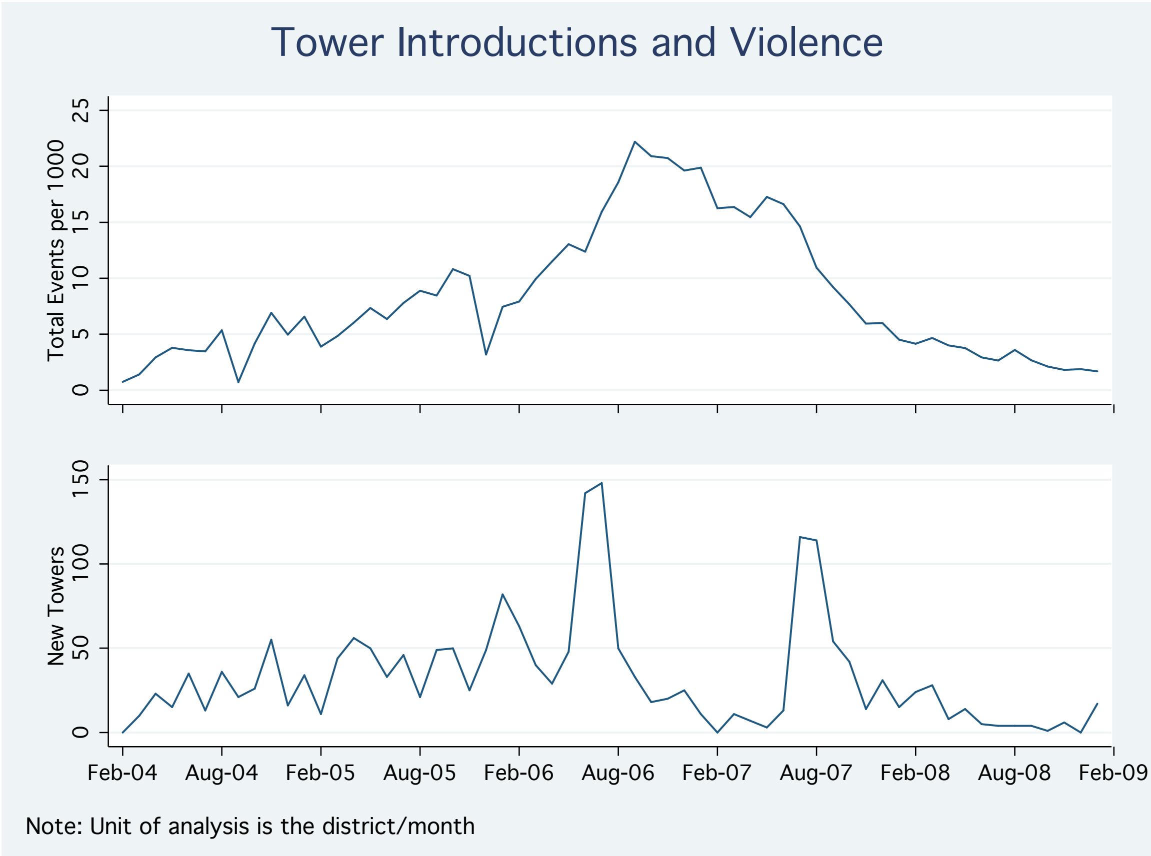
Notes: Unit of analysis for violence is district/month, February '04 – January '09. Violent events based on data on MNF-I SIGACT-III database. Civilian casualty data from Iraq Body Count collaboration with ESOC. Cell tower data provided by Zain Iraq. Population data from LandScan (2008) gridded population data and WFP surveys (2003, 2005, and 2007). Analysis restricted to 63 districts in which Zain operated during period under study.

A05. Figure: Patterns of violence and network expansion across Iraq's 20 most violent districts



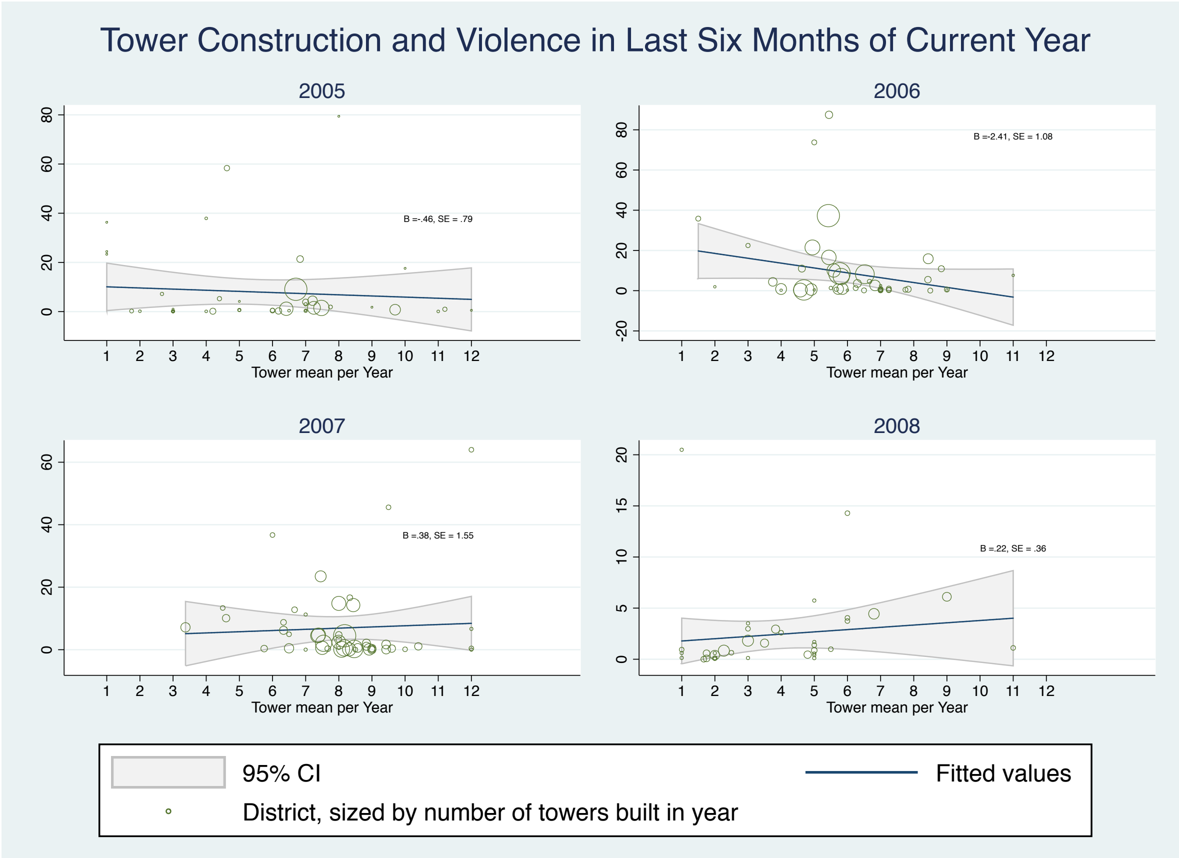
Note: Unit of analysis is the district month. Violence data are from MNF-I SIGACT-III database. Population data are from World Food Program Food Security and Vulnerability Analysis surveys fielded in 2004:I, 2005:II, and 2007:I. Data on cell phone tower installations provided by Zain Iraq.

A06. Figure: National trends in violence and network expansion



Note: Unit of analysis is the month. Violence data are from MNF-I SIGACT-III database. Population data are from World Food Program Food Security and Vulnerability Analysis surveys fielded in 2004:I, 2005:II, and 2007:I. Data on cell phone tower installations provided by Zain Iraq.

A07. Figure: Relationship beterrn Current Year Violence and Tower Construction at District/Month



A08. Table: Relationship between violence and average month of tower introduction

		Full Sample	2005	2006	2007	2008
Panel 1: DV = Aggregate Violence in July-December of Previous Year	Panel 1A: Bivariate Regression					
	July-December Violence	0.299	0.254	-0.937*	-1.034	1.561
		(0.55)	(0.38)	(0.48)	(2.36)	(1.45)
	Observations	177	44	49	48	36
	R-squared	0.00	0.01	0.09	0.01	0.04
	Panel 1B: Sect Fixed Effects					
	July-December Violence	0.219	0.283	-0.731	-0.250	-2.138
		(0.46)	(0.19)	(0.79)	(2.15)	(3.01)
	Observations	177	44	49	48	36
	R-squared	0.32	0.39	0.44	0.49	0.42
Panel 2: DV = Aggregate Violence in January-July of Current Year	Panel 2A: Bivariate Regression	Full Sample	2005	2006	2007	2008
	January-June Violence	0.662	0.143	-1.721*	0.663	0.969*
		(0.63)	(0.54)	(0.87)	(3.09)	(0.55)
	Observations	177	44	49	48	36
	R-squared	0.01	0.00	0.08	0.00	0.11
	Panel 2B: Sect Fixed Effects					
	January-June Violence	0.593	0.296	-1.342	2.015	-0.279
		(0.68)	(0.32)	(1.46)	(3.02)	(0.69)
	Observations	177	44	49	48	36
	R-squared	0.29	0.47	0.44	0.39	0.44
Panel 3: DV = Aggregate Violence in July-December of Current Year	Panel 3A: Bivariate Regression	Full Sample	2005	2006	2007	2008
	July-December Current Year Violence	-0.0707	-0.465	-2.413**	0.383	0.223
		(0.40)	(0.79)	(1.09)	(1.55)	(0.36)
	Observations	177	44	49	48	36
	R-squared	0.00	0.01	0.06	0.00	0.02
	Panel 3B: Fixed Effects					
	July-December Current Year Violence	-0.141	-0.157	-1.829	0.874	-0.614
		(0.32)	(0.40)	(2.01)	(1.56)	(0.81)
	Observations	177	44	49	48	36
	R-squared	0.29	0.56	0.47	0.36	0.40

Note: Robust standard errors in parentheses for all regressions, clustered by sectarian region for regressions with sect fixed-effects. Sect fixed effects account for distinct mean levels of violence in 9 Sunni/Kurd districts, 13 mixed districts, and 41 majority Shia districts. 75 of 252 district-years had no towers introduced and so are not included in regressions, representing 40 different districts of which 9 are predominantly Sunni or Kurdish, 7 are mixed, and 24 are predominantly Shia. Constants not reported. *** p<0.01, ** p<0.05, * p<0.1.

A09. Table: Descriptive statistics for the tower-level data (15-day periods)

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Panel A: Violence Variables – Full Sample					
SIGACTs	29,744	8.94	15.20	0	224
Direct Fire	29,744	3.60	7.15	0	127
Indirect Fire	29,744	0.40	1.89	0	50
IEDs	29,744	4.09	7.39	0	127
Panel B: Tower Areas Characteristics – Full Sample					
Area (km²)	1,859	87	118	50	449
Proportion New	1,859	0.13	0.28	0	1
Population	1,859	354,041	308,394	0	1,445,185
Proportion Urban	1,859	0.92	0.27	0	1
Proportion Sunni	1,859	0.22	0.26	0	1
Proportion Shia	1,859	0.78	0.26	0	1
Panel C: Violence Variables – Less than 50% New					
SIGACTs	26,368	9.87	15.77	0	224
Direct Fire	26,368	4.00	7.46	0	127
Indirect Fire	26,368	0.44	1.99	0	50
IEDs	26,368	4.50	7.68	0	127
Panel D: Tower Areas Characteristics – Less than 50% New					
Area (km²)	1,648	67.40	81.69	49.9	449
Proportion New	1,648	0.03	0.08	0	0.49
Population	1,648	394,371	303,913	3,770	1,445,185
Proportion Urban	1,648	0.97	0.18	0	1
Proportion Sunni	1,648	0.21	0.24	0	1
Proportion Shia	1,648	0.78	0.24	0	1
Panel E: Violence Variables – More than 50% New					
SIGACTs	3,376	1.67	5.75	0	78
Direct Fire	3,376	0.52	2.14	0	33
Indirect Fire	3,376	0.12	0.76	0	17
IEDs	3,376	0.89	3.04	0	42
Panel F: Tower Areas Characteristics – More than 50% New					
Area (km²)	211	254.5	200.2	49.9	449
Proportion New	211	0.87	0.16	0.50	1
Population	211	39,046	67,991	0	496943.00
Proportion Urban	211	0.55	0.50	0	1
Proportion Sunni	211	0.25	0.37	0	1
Proportion Shia	211	0.74	0.38	0	1

Notes: Unit of analysis for violence is tower/15-day period. Tower coverage areas created by a 4km radius around cell phone towers in urban areas and 12km radius in rural areas. Violent events based on data on MNF-I SIGACT-III database. Cell tower data provided by Zain Iraq. Population data from LandScan (2008) and gridded population data. Includes only towers with at least 8 periods before and after onair date.

A10. Table: Regression results with spatial lag

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable:	FD of SIG /100,000						
Lagged First Difference of Tower Count	-0.0719 (0.048)	-0.0812 (0.049)	-0.108* (0.056)	-0.140** (0.069)	-0.0841 (0.054)	-0.0916 (0.056)	-0.180* (0.097)
Existing Tower Count	0.0384*** (0.0091)	0.0379*** (0.0090)	0.0323*** (0.0079)	0.0323*** (0.0080)	0.0366*** (0.0083)	0.0341*** (0.0080)	0.0344*** (0.0087)
Observations	3654	3654	3654	3654	3654	3654	3654
R-squared	0.09	0.10	0.12	0.12	0.10	0.12	0.14
Time FE	Half	Quarter	Month	Month	Sect X Half	Sect X Quarter	Province X Quarter
Space FE	No	No	No	District	No	No	No
First Differences	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Analysis restricted to 63 districts in which Zain Iraq operated during period under study. Robust standard errors, clustered at the district level in parentheses. Spatial lags are total of given variable in neighboring districts, Each model's fixed effects are noted. Estimates which are significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***). Violent events based on data on MNF-I SIGACT-III database. Cell tower data provided by Zain Iraq. Population data from LandScan (2008) gridded population data and WFP surveys (2003, 2005, and 2007).

A11. Checking for omitted variable bias in the tower-level results

To check for omitted variable bias we use temporal and geographic placebo tests. Table A below places the number of new towers introduced in the next month on the RHS (the lead difference) and Table B places the number of towers introduced in neighboring districts on the RHS (the spatial lag of the lagged difference). None of the coefficients are significant in the differenced specifications, providing additional confidence that the combination of differencing and fixed effects in Table 1 properly identify the impact of tower construction at the district-month level.

Table A. Temporal Placebo Test of Impact of Increased Cell Phone Coverage on Total Attacks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable:	FD of SIG /100,000	FD of SIG /100,000	FD of SIG /100,000	FD of SIG /100,000	FD of SIG /100,000	FD of SIG /100,000	FD of SIG /100,000
Lead FD of Tower Count	0.0148	0.00348	0.0728	0.0948	-0.00794	-0.0351	-0.115
	(0.048)	(0.052)	(0.064)	(0.081)	(0.050)	(0.053)	(0.10)
Observations	3654	3654	3654	3654	3654	3654	3654
R-squared	0.01	0.02	0.07	0.07	0.05	0.07	0.09
Time FE	Half	Quarter	Month	Month	Sect X Half	Sect X Quarter	Province X Quarter
Space FE	No	No	No	District	No	No	No
First Differences	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Analysis restricted to 63 districts in which Zain Iraq operated during period under study. Robust standard errors, clustered at the district level in parentheses. Each model's fixed effects are noted. Estimates which are significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***). Violent events based on data on MNF-I SIGACT-III database. Cell tower data provided by Zain Iraq. Population data from LandScan (2008) gridded population data and WFP surveys (2003, 2005, and 2007).

Table B. Geographic Placebo Test of Impact of Increased Cell Phone Coverage on Total Attacks

Dependent Variable:	(1) FD of SIG /100,000	(2) FD of SIG /100,000	(3) FD of SIG /100,000	(4) FD of SIG /100,000	(5) FD of SIG /100,000	(6) FD of SIG /100,000	(7) FD of SIG /100,000
Lagged FD of Tower Count in Neighboring Districts	-0.158	-0.185	-0.217	-0.285	-0.126	-0.106	-0.236
	(0.14)	(0.19)	(0.25)	(0.34)	(0.16)	(0.16)	(0.42)
Observations	3654	3654	3654	3654	3654	3654	3654
R-squared	0.01	0.02	0.12	0.12	0.04	0.07	0.07
Time FE	Half	Quarter	Month	Month	Sect X Half	Sect X Quarter	Province X Quarter
Space FE	No	No	No	District	No	No	No
First Differences	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Analysis restricted to 63 districts in which Zain Iraq operated during period under study. Robust standard errors, clustered at the district level in parentheses. Each model's fixed effects are noted. Estimates which are significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***). Violent events based on data on MNF-I SIGACT-III database. Cell tower data provided by Zain Iraq. Population data from LandScan (2008) gridded population data and WFP surveys (2003, 2005, and 2007).

A12. Checking for the direct impact of violence on future tower construction

While we argued that there should be little impact of violence on future tower construction given that the cell phone providers reported insurgent violence did not interfere with tower construction, violence might impact tower construction in less direct ways. The providers reported that the main source of month-to-month delays in tower construction arose from the need to secure clear title to properties before building. Past sectarian violence, which is weakly correlated with insurgent attacks ($\rho = .203$), clearly drove population movements which likely made it harder to secure clear title to desired tower locations, thereby delaying tower construction. If that dynamic introduced bias into our estimates we should find that controlling for various kinds of sectarian violence alters the results. Table A shows this is not the case. Panel (A) reports the core specification of columns (6 and 7) from table (2), Panel (B) controls for total sectarian violence in a number of ways, and Panel (C) controls for targeted killings by sectarian organizations. None of the controls significantly alter our estimates of the impact of cellular coverage, providing additional confidence in the estimates in Table 1.

Table A. Impact of Increased Cell Phone Coverage on Total Attacks controlling for Past Sectarian Violence

Dependent Variable: First Differences in SIGACTs/100,000	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A: Core Specifications		*Panel B: Controls for Total Sectarian Violence*			*Panel B: Controls for Targeted Killings by Sectarian Militias*		
Lagged FD of Towers	-0.116**	-0.151**	-0.143**	-0.137*	-0.166**	-0.146**	-0.144**	-0.167**
	(0.056)	(0.070)	(0.070)	(0.069)	(0.072)	(0.071)	(0.071)	(0.073)
FD of Sectarian Violence	0.0259	0.0260	0.00946	-0.0392		0.0273	-0.0307	
	(0.031)	(0.031)	(0.048)	(0.051)		(0.045)	(0.061)	
Lagged FD of Sectarian Violence			-0.0347	-0.112		0.00724	-0.0797	
			(0.047)	(0.072)		(0.055)	(0.098)	
Second Lag FD of Sectarian Violence				-0.114			-0.117	
				(0.069)			(0.084)	
Sectarian Violence 3-Month Lagged Moving Average Lag					-0.143**			-0.209
					(0.066)			(0.15)
Observations	3717	3717	3717	3654	3654	3654	3654	3654
R-squared	0.28	0.28	0.31	0.01	0.01	0.03	0.06	0.07
Time FE	Month	Month	Month	Month	Month	Month	Month	Month
Space FE	No	District	District	District	District	District	District	District
Sectarian FE	Yes	Yes	2 Lags	3 Lags	Lagged Moving Avg.	2 Lags	3 Lags	Lagged Moving Avg.
First Differences	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Analysis restricted to 63 districts in which Zain Iraq operated during period under study. Robust standard errors, clustered at the district level in parentheses. Each model's fixed effects are noted. Estimates which are significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***). Violent events based on data on MNF-I SIGACT-III database.

A13. Checking for changes in insurgent effectiveness caused by cell phone coverage

Another possibility, that insurgents trade quality for quantity when coverage increases, does not impact the validity of our net reduced form estimates, but does raise the issue of what the results imply. If cell phone coverage allows insurgents to be more effective with fewer attacks, then the policy implications of our findings are the opposite of what a more straightforward interpretation would suggest. The question is thus whether enhanced coverage allows insurgent to substitute quantity for quality at rates that should call into question the assessment that fewer attacks indicate a harder operating environment for insurgents.

Unfortunately, checking for such substitution is not possible at the district-month level, as the SIGACT data do not include information on the consequences of attacks. What we can do is check whether there is substantial variation in the correlation between attack rates and casualty rates at the provincial level using the iCasualties.org data which give monthly figures for U.S. forces killed by province.[2] It turns out there is very little change over time in that relationship. The bivariate monthly correlation between total attacks and casualties is quite high, .61 for the entire period, and remains similarly strong by year, ranging from .51 in 2005 to .80 in 2007. Once we account for regional differences by using province fixed effects in a regression framework, the conditional correlation between casualties and total attacks is positive but statistically insignificant and does not change over time.[3] This consistency is hard to square with strong substitution effects, making us relatively confident that the reduced form relationship we identify shows that increased coverage makes it harder for insurgents to conduct attacks.

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[2] For various tabulations of the data see www.iCasualties.org. We thank Radha Iyengar for providing these data in a readily usable Stata file.

[3] Formally, we allow the slope of the casualty-incident relationship to vary by year using interaction terms and find no statistically meaningful slope shifts by year.

A14. Table: District-level results by attack type and sectarian region

Dependent Variable: Attacks/100,000	(1) All Attacks	(2) Direct Fire	(3) Indirect Attacks	(4) IED Attempts	(5) IEDs Cleared / Total Attempts
Panel A: Mixed Areas					
Tower First Differences	-0.251	-0.0836	-0.0007	-0.133	0.0096
	(0.19)	(0.077)	(0.0068)	(0.091)	(0.011)
Observations	580	580	580	580	580
R-squared	0.30	0.24	0.35	0.25	0.10
Panel B: Kurdish/Shia Areas					
Tower First Differences	-0.00960	-0.00668	0.00144	0.0237	-0.0010
	(0.058)	(0.027)	(0.0074)	(0.020)	(0.005)
Observations	2436	2436	2436	2436	1134
R-squared	0.10	0.08	0.10	0.04	0.04
Panel C: Sunni Areas					
Tower First Differences	-2.259*	-0.877**	0.133	-1.048	-0.0612
	(1.07)	(0.39)	(0.13)	(0.71)	(0.034)
Observations	638	638	638	638	297
R-squared	0.23	0.10	0.21	0.21	0.12
Panel D: Mixed and Sunni Areas Combined					
Tower First Differences	-0.496	-0.158	0.0130	-0.315*	-0.0035
	(0.29)	(0.12)	(0.015)	(0.16)	(0.012)
Observations	1218	1218	1218	1218	567
R-squared	0.18	0.08	0.16	0.15	0.04

Notes: Analysis restricted to 63 districts in which Zain operated during period under study. Robust standard errors, clustered at the district level in parentheses. All results include month and district fixed effects. Estimates which are significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***). Column (5) calculated only for period after September 2006 when data distinguish successful and failed IED attacks.

A15. Table: Tower-level results by attack type and period

Dependent Variable:	(1) All Attacks	(2) Direct Fire	(3) Indirect Fire	(4) Total IED Attempts
Panel A: Excluding towers built 8/06 to 7/07				
Post	-0.685***	-0.408***	-0.0932**	-0.176*
	(0.21)	(0.11)	(0.040)	(0.098)
*Post*New*	-0.545*	-0.0765	0.147**	-0.475***
	(0.32)	(0.17)	(0.060)	(0.14)
Observations	22144	22144	22144	22144
R-squared	0.71	0.61	0.34	0.76
Panel B: Dropping 2008				
Post	-0.379**	-0.275***	-0.0561	-0.164*
	(0.18)	(0.097)	(0.043)	(0.088)
*Post*New*	-0.696*	-0.181	0.0926*	-0.293**
	(0.36)	(0.19)	(0.053)	(0.13)
Observations	28208	28208	28208	28208
R-squared	0.79	0.69	0.31	0.82

Notes: Unit of analysis is tower areas for 15-day periods in relative time from tower onair date. Coverage areas created by a 4km radius around cell phone towers in urban areas and 12km radius in rural areas. New towers are those whose catchment is at least 20% new coverage. Robust standard errors, clustered at the tower level in parentheses. All specifications include tower and quarter fixed effects. Estimates significant at the 0.05 (0.10, 0.01) level are marked with at ** (*, ***).